QUEUES

Write a generic data type for a deque and a randomized queue. The goal of this assignment is to implement elementary data structures using arrays and linked lists, and to introduce you to generics and iterators.

Dequeue. A *double-ended queue* or *deque* (pronounced "deck") is a generalization of a stack and a queue that supports adding and removing items from either the front or the back of the data structure. Create a generic data type `Deque` that implements the following API:

```
public class Deque<Item> implements Iterable<Item> {

    // construct an empty deque
    public Deque()

    // is the deque empty?
    public boolean isEmpty()

    // return the number of items on the deque
    public int size()

    // add the item to the front
    public void addFirst(Item item)

    // add the item to the back
    public void addLast(Item item)

    // remove and return the item from the front
    public Item removeFirst()

    // remove and return the item from the back
    public Item removeLast()

    // return an iterator over items in order from front to back
    public Iterator<Item> iterator()

    // unit testing (required)
    public static void main(String[] args)

}
```

Corner cases. Throw the specified exception for the following corner cases:

- Throw an `IllegalArgumentException` if the client calls either `addFirst()` or `addLast()` with a `null` argument.
- Throw a `java.util.NoSuchElementException` if the client calls either `removeFirst()` or `removeLast` when the deque is empty.
- Throw a `java.util.NoSuchElementException` if the client calls the `next()` method in the iterator when there are no more items to return.
- Throw an `UnsupportedOperationException` if the client calls the `remove()` method in the iterator.

Unit testing. Your `main()` method must call directly every public constructor and method to help verify that they work as prescribed (e.g., by printing results to standard output).

Performance requirements. Your deque implementation must support each deque operation (including construction) in *constant worst-case time*. A deque containing n items must use at most $48n + 192$ bytes of memory. Additionally, your iterator implementation must support each operation (including construction) in *constant worst-case time*.

Randomized queue. A *randomized queue* is similar to a stack or queue, except that the item removed is chosen uniformly

at random among items in the data structure. Create a generic data type `RandomizedQueue` that implements the following API:

```
public class RandomizedQueue<Item> implements Iterable<Item> {

    // construct an empty randomized queue
    public RandomizedQueue()

    // is the randomized queue empty?
    public boolean isEmpty()

    // return the number of items on the randomized queue
    public int size()

    // add the item
    public void enqueue(Item item)

    // remove and return a random item
    public Item dequeue()

    // return a random item (but do not remove it)
    public Item sample()

    // return an independent iterator over items in random order
    public Iterator<Item> iterator()

    // unit testing (required)
    public static void main(String[] args)

}
```

Iterator. Each iterator must return the items in uniformly random order. The order of two or more iterators to the same randomized queue must be *mutually independent*; each iterator must maintain its own random order.

Corner cases. Throw the specified exception for the following corner cases:

- Throw an `IllegalArgumentException` if the client calls `enqueue()` with a `null` argument.
- Throw a `java.util.NoSuchElementException` if the client calls either `sample()` or `dequeue()` when the randomized queue is empty.
- Throw a `java.util.NoSuchElementException` if the client calls the `next()` method in the iterator when there are no more items to return.
- Throw an `UnsupportedOperationException` if the client calls the `remove()` method in the iterator.

Unit testing. Your `main()` method must call directly every public constructor and method to verify that they work as prescribed (e.g., by printing results to standard output).

Performance requirements. Your randomized queue implementation must support each randomized queue operation (besides creating an iterator) in *constant amortized time*. That is, any intermixed sequence of m randomized queue operations (starting from an empty queue) must take at most cm steps in the worst case, for some constant c. A randomized queue containing n items must use at most $48n + 192$ bytes of memory. Additionally, your iterator implementation must support operations `next()` and `hasNext()` in *constant worst-case time*; and construction in *linear time*; you may (and will need to) use a linear amount of extra memory per iterator.

Client. Write a client program `Permutation.java` that takes an integer k as a command-line argument; reads a sequence of strings from standard input using `StdIn.readString()`; and prints exactly k of them, uniformly at random. Print each item from the sequence at most once.

```
~/Desktop/queues> cat distinct.txt
A B C D E F G H I

~/Desktop/queues> java Permutation 3 < distinct.txt
C
G
A

~/Desktop/queues> java Permutation 3 < distinct.txt
E
F
G
```

```
~/Desktop/queues> cat duplicates.txt
AA BB BB BB BB BB CC CC

~/Desktop/queues> java Permutation 8 < duplicates.txt
BB
AA
BB
CC
BB
BB
CC
BB
```

Your program must implement the following API:

```
public class Permutation {
   public static void main(String[] args)
}
```

Command-line argument. You may assume that $0 \le k \le n$, where n is the number of string on standard input. Note that you are not given n.

Performance requirements. The running time of `Permutation` must be linear in the size of the input. You may use only a constant amount of memory plus either one `Deque` or `RandomizedQueue` object of maximum size at most n. (For an extra challenge and a small amount of extra credit, use only one `Deque` or `RandomizedQueue` object of maximum size at most k.)

Web submission. Submit a .zip file containing only `RandomizedQueue.java`, `Deque.java`, and `Permutation.java`. Your submission may not call library functions except those in `StdIn`, `StdOut`, `StdRandom`, `java.lang`, `java.util.Iterator`, and `java.util.NoSuchElementException`. In particular, do not use either `java.util.LinkedList` or `java.util.ArrayList`.

This assignment was developed by Bob Sedgewick and Kevin Wayne.
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